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A Perspective of the Japanese FGCS Project

by

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The Japanese Fifth Generation Computer Systems Project, or FGCS project as we call it, is aimed at researching and developing the basic technologies deemed necessary to build computer systems equipped with knowledge information processing capabilities of the type expected to come into widespread use during and beyond the 1990's. These technologies will be put to good use in the creation of various kinds of practical knowledge information processing computer systems, which should account for a major share of the computer market in future.

This project itself, however, is not aimed at developing computer systems for commercial purposes. Rather, the objective is to build prototypes of knowledge information processing systems, or KIPS, which will be based on the research and development of technologies basic to those systems. All patents taken out on technologies developed through this project will become the property of the Japanese Goverment, but their utilization will be as widespread as possible. When it comes to the commercialization of these technologies, it is felt that this should be handled by individual companies as they see fit, without the participation or financial or other support of the Japanese Government. Therfore, should Japanese companies fail to capitalize on the fruits of this project, instead allowing them to fall into the hands of giants in the industry such as IBM, for example, then we will more than likely witness the emergence of an even bigger and more powerful IBM. Japanese companies aren't that blind to realities, however. Although there were a number of controversies and areas of disagreement with Japanese companies during the initial stages of this project, at present they fully support the aims of the project and have proven instrumental in promoting its progress.

It should also be pointed out, that the Japanese FGCS project is designed to carry out only a portion of the overall research and development work involved in crearing the new software and hardware technologies deemed necessary for the realization of knowledge information processing systems. In order to develop all the technologies that will be required for these computer systems of the future, a number of other national projects are essential . Some of these other projects got underway about the same time as the FGCS project and are still in progress, while others have already been completed. For example, R&D into appropriate communications networks to link together the advanced computer systems being envisioned for the future is to commence next year with the testing of the Information Network System project, abbreviated INS, which is being carried out primarily by the Nippon Telegraph and Telephone Public Corporation, better known internationally as NTT. Then there is also the Super-Computer(High-Speed Computing System for Scientific and Technological Use) Project that got started back in 1981, and which is designed to develop an ultra-high-speed computer for scientific and technological computations, plus the new high-speed Josephson Junction and GaAs devices that will be essential for achieving the desired computing speeds. As for pattern information processing, VLSI and software engineering, a number of projects devoted towards these ends have been completed within the past few years, providing our FGCS project with various developments vital to its progress.

Next, I would like to give you a brief description of the specific objectives, approaches and current status of the Japanese FGCS project.

I will begin by outlining some of the more specific objectives we hope to attain via this project.

One of the principal goals of out project is to develop natural man-machine interface systems. The human interface should enable fifth generation computer systems to recognize and understand speech and natural language inputs. Image understanding functions will also be built into the human interface to enable data in the form of sophisticated images and graphics to be input and output as well. when operators are able to interface with their computers in a conversational mode, then the human interface will have become much richer and more efficient. Once this has become a reality, we will have taken a quantum leap towards processing the "semantics" of data, something symbolized by the term "understanding."

The basic functions envisioned for fifth generation computer systems will center around a knowledge base function. A broad, comprehensive knowledge base will be constructed from knowledge selected from a variety of fields. A dictionary for the natural language processing, an algorithm bank for the intelligent programming system, hardware specifications for maintenance purposes and even the contents of various user's manuals will all be made into knowledge bases. By so doing, the computer system will be capable of utilizing appropriate knowledge bases to solve problems in response to various inquiries put to it by users. In other words, fifth generation computer systems will provide users with inference and problem-solving functions.

To achieve this, the concepts of programs and data or databases will have to be integrated into the broader concept of knowledge and knowledge bases. In other words, what has functioned in conventional computers as a database will be upgraded to the level of a knowledge base for fifth generation computers. By incorporating various, more powerful knouledge bases into inference and problem-solving systems, we should be able to realize the kinds of intelligent functions users require. Of course, this doesn't mean that such an advanced system will be realized by fifth generation computer systems all at once, but they should prove a big step in that direction.

The Japanese FGCS project also has as one of its goals the breaking of new ground in the area of practical systems for specification and verification functions for programming systems and languages. An automatic program synthesis system should also be capable of being achieved. At that time, all knowledge concerning programmed object domains, programming languages, program construction methods and previously prepared program packages will be provided as knowledge bases. The intelligent programming system will possess advanced inference and problem-solving functions which will manipulate the knowledge contained in these knowledge bases to guide the user during programming. The intelligent programming system should become a typical applications system in fifth generation computers.

The programming language will be an advanced, non-procedural language based on logic-programming. This will make it possible to express programs in the form of knowledge. We have labelled this programming language the Kernel Language for two specific reasons. First is that it is a language that will stipulate the architecture and hardware interfaces of fifth generation computer systems. Second, it will be capable of being implemented in common with richer end-user languages, and will be a "semantics" representation language. This Kernel Language will literally be the "kernel" or "core" of Japanese fifth generation computer systems, and will differ qualitatively from other languages in existence today, including Ada, which tend to converge with FORTRAN, COBOL, ALGOL and PL/I.

Our goals concerning computer architecture will be based on the thinking surrounding reduction machines and data flow machines, and will be built upon the concept of a highly parallel processing architecture. This will enable fifth generation computer systems to operete on the basis of parallel processing as compared to the sequential processing of conventional computers. Then, a high-level language machine architecture and database machine architecture will be built on this parallel processing architecture to support the Kernel Language. Maximum use will be made of VLSI technology to realize these architectures. The basic unit modules that will be needed to construct the optimum systems in various utilization forms, from small-scale systems to large-scale systems, will also be realized using these architecture technologies.

It will also be necessary to develop various applocation systems in addition to the above described functions. The most representative of the basic application systems sought to be developed through the Japanese FGCS project are an expert system, intelligent programming system machine translation system and VLSI-CAD system. The development of basic application systems such as these should demonstrate the overall functions of fifth generation computer systems.

A number of prototype systems are to be constructed during the course of Japanese FGCS project. These will not be aimed at achieving special computers possessing only certain specific functions, but rather are intended to develop new generation general-purpose computers worthy of being called fifth generation machines. The purpose of research into artificial intelligence is to shed light on human intellectual functions and develop a usefull system capable of supporting and expanding these human intellectual functions. We are convinced that it is the objectives laid down for artificial intelligence research that will give direction to all other future work in the field of information processing technology.

Next, I would like to touch on the kinds of approaches we are employing in the course of our research and development work.

To reiterate, our goal is to realize a computer capable of processing knowledge. However, we don't intend to limit this knowledge to a certain field, but rather are bent on realizing intelligent functions that cover a fairly wide range of fields. As any AI researcher knows, limiting the fields of knowledge covered by a computer will increase its capabilities, while broadening the scope of that knowledge will reduce them. And trying to cover too wide a range of knowledge can all but eliminate a computer's intellectual abilities. All researchers have a pretty fair grasp of the depth and breadth of human intelligence. This being the case, then, just what type of intellectual functions are the members of the Japanese FGCS project considering for incorporation into fifth generation computer systems, and how are we planning to introduce these functions into the computer?

We have decided on two broad approaches, one being the "Top-Down" approach, and the other the "Bottom-Up" approach. The "Top-Down" approach will be employed to advance our understanding of intelligence, more specifically, knowledge processing functions. Knowledge can be broadly divided into specialized and general knowledge. In the area of specialized knowledge, we will be prototyping and testing expert systems for various suitable fields. When it comes to generalized knowledge, however, we will be focusing on elucidating symbolic(language) knowledge. After all, symbolization itself is at the root of intellectual functions. An understanding of symbolic knowledge can be avhieved by shedding light on the language processing and understanding mechanisms used by we humans to express our ideas. The languages we intend to use will consist of natural language which is capable of expressing everyday common human knowledge, a mathematical language capable of expressing logical and algebraic knowledge and a programming language to express the knowledge contained in programs and databases.

The "Bottom-Up" approach will employ logic programming represented in PROLOG as the first approximation to the knowledge information processing system. PROLOG is written in a primitive form, and as such includes, or can be made to include all the basic functions necessary for knowledge processing. I will attempt to explain here just why this is felt to be possible. First of all, PROLOG possesses an extremely natural paradigm. It can therefore be made to incorporate all of the qualities of existing programming languages that deserve to be carried over and continued. The PROLOG language also possesses a simple, well-arranged structure. Secondly, PROLOG has an advanced symbolic processing function. Knowledge processing is carried out on the basis of symbol manipulations, and PROLOG has an advanced symbol manipulating function which makes use of unification. Thirdly, PROLOG possesses a sophisticated database function. Data retrieval and procedure calling are incorporated into a single mechanism. The uniformity of data and programs like this is the first step toward the realization of knowledge bases from databases. Fourthly, PROLOG possesses an inference function. In other words, it possesses a function that enables it to execute a program while making appropriate selections from among a number of possibilities. Normally, this function is realized by means of a top-down, depth-first mechamism. Fifthly, PROLOG enables the construction of an effective processing system or machine. As evidenced by the PROLOG systems developed by Edinburgh University, PROLOG enables processing systems to be put together that are capable of standing up to use even on ordinary computers. Therfore, if a PROLOG machine possessing the appropriate architecture can be developed, we can guarantee its practicality.

It is for these reasons that ICOT is pursuing its "Bottom-Up" research approach using PROLOG to prototype and test numerous expert systems, to test natural language and other understanding mechanisms and to extract common mechamisms that will become the bases for knowledge processing, while at the same time raising the capabilities of PROLOG itself to still higher levels.

Up to this point, I have attempted to outline the R&D approach for software above the targetted Kernel Language level. Next, I would like to attempt to describe our plans for the architecture below the Kernel Language level.

The architecture for the FGCS project is being researched from the standpoint of a PROLOG machine capable of the high-speed processing of large volumes of data, or in this case knowledge. Two approaches are being utilized to achieve this goal. The first involves coming up with ideas for totally new processing mechanisms, and the subsequent prototyping and testing of machines based on these ideas. The second approach calles for making improvements to already existing mechanisms, designing and building machines capable of withstanding the utilization demands that will be placed on them by fifth generation computer systems.

The first approach involves research into highly parallel PROLOG processing mechanisms based on reduction, data flow and various other methods, followed by the construction of simulators and the prototyping of basic modules. PROLOG, with its non-determinancy, possesses superior parallelism and parallel processing description capabilities, as is clearly shown with Shapiro's Concurrent PROLOG and Clark`s PARLOG. Our research in this area is proceeding along under the name "Parallel Inference Machine."

The second approach is aimed at developing advanced personal machines and database machines. The personal machine is actually a PROLOG machine that corresponds to a Lisp machine. By means of constructing this machine, we should be able to discover and prove a number of new facts concerning software, languages and architecture in general. The development of this machine, of which I am the individual directly in charge, is proceeding under the name "Sequential Inference Machine." At this point in our work, we have already completed the detailed design of the programming and operating systems, and have commenced constructing the hardware. This machine will be used as a tool in the research and development work to be undertaken during the intermediate stage of the project. And of course, improvement and expansion of the machine itself will be carried out in parallel to its role as an R&D tool. We are planning to produce quite a large number of Sequential Inference Machines at the start of the intermediate stage of the project and connect them together via a network so that leading researchers located in various parts of Japan will be able to participate in the project from their remote locations. If we then extend this network internationally, we would further increase the number of locations from which joint research activities could be carried out.

I should also briefly explain the advanced database machine. First, PROLOG will have to be linked together with Relational Database. We are venturing forth on a new line of development in this area under the name "Logic Database." The relational database machine(RDBM) is an example of a successful non-von-Neumann type machine, as well as a parallel processing machine for large volumes of relational data. We are currently engaged in the development of an advanced RDBM as the first step in the realization of a knowledge base machine. This RDBM will also be utilized as a R&D tool once we enter the intermediate stage of the FGCS project. We intend to expand this machines capabilities and develop it until it reaches knowledge base proportions.

This completes my brief description of the approaches being utilized in the carrying out of our R&D activities for the FGCS project, and the current status of that project. Let me finish my talk by touching on a few points concerning the R&D system being employed in this project.

The FGCS project is comprised of numerous revolutionary themes, and requires the participation of large numbers of leading researchers from a variety of computer-related fields. However, there simply aren't enough of these kinds of researchers in Japan. There are also other considerations peculiar to Japan which prevent our project from obtaining the kinds of cooperation we need from university researchers in particular. We are striving to improve the R&D system in Japan from a number of standpoints, but a revolutionary project such as the FGCS project calls for a revolutionary R&D system.

total system	Knowledge Information Processing System
basic application system	Machine Translation System
	Expert System
	Intelligent Programming System
	VLSI-CAD System
man-machine interface	Natural Language and Speech Understanding Mechanism
	Picture Understanding Mechanism
basic mechanism	Knowledge Base Mechanism
	Inference and Problem Solving Mechanism
programming language	Logic Programming Language(Kernel Language)
architecture	High Level Language Machine Architecture
	Database Machine Architecture
	Highly Parallel Machine Architecture
	(Reduction Machine, Data Flow Machine etc.)
hardware	VLSI